Battery Research & Development Need for Military Vehicle Application

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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14. ABSTRACT

The Battery Management System (BMS) laboratory is TARDEC's Lab for analyzing and evaluating prototype, near production ready, and commercial-off-the-shelf BMS units for lead acid and Li-ion batteries. BMS evaluation in this lab supports the PM/PEO to determine if the system is ready for fielding. Testing also aids TARDEC in updating the BMS specification that is used by the customer for battery management qualifications that will be used in fielded vehicles.

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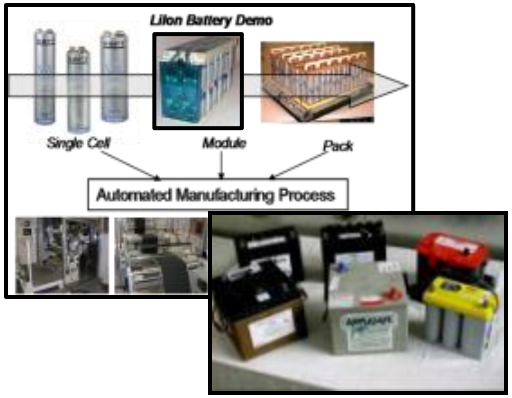
Energy Storage

Challenges we have:

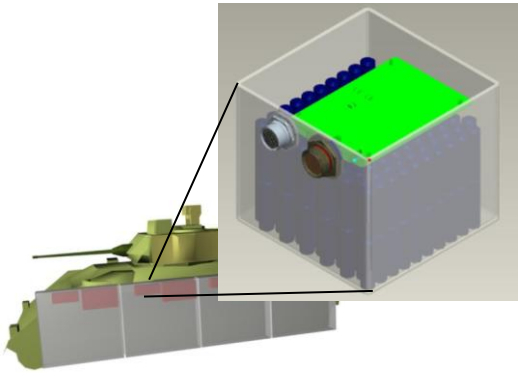
- Delivering reliable battery solutions in standardized military form factors
- Safety – Understanding thermal runaway process and its control, improved BMS and alternative cell technologies.
- Developing energy storage systems with higher energy and higher power densities (focus on designs and chemistries).
- Manufacturing process development, quality and cost control.

Solutions we are investigating:

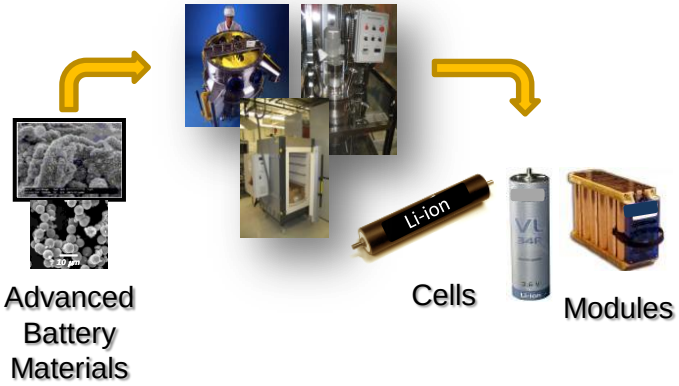
Development of advanced manufacturing technologies & form factor standardization



Develop of Power Brick battery for EM Armor and pulse power applications



R&D of new materials to improve performance and safety



Where we need your help:

- Identify materials/designs/technologies to significantly improve safety
- Develop technologies to improve both energy and power density as well as life (calendar and cycle).
- Develop energy storage systems that focus on standardized form factors (6T, 4HN, Group 31 and Group 34).
- Cost reduction technologies

Program Collaboration & DOD Customers

PEO Soldier

DOD Customers

PEO GCS

PEO CS/CSS

Battery Partners

CERDEC Soldier

Material Developers

Battery Partners

TARDEC Ground

OEMs (Commercial / Defense)

Industrial Developers

AFRL Air

Battery Partners

AVPTA

Battery Developers

Material Developers

USABC

DOE

Universities

ANL

National Labs

ARL

Industrial Developers

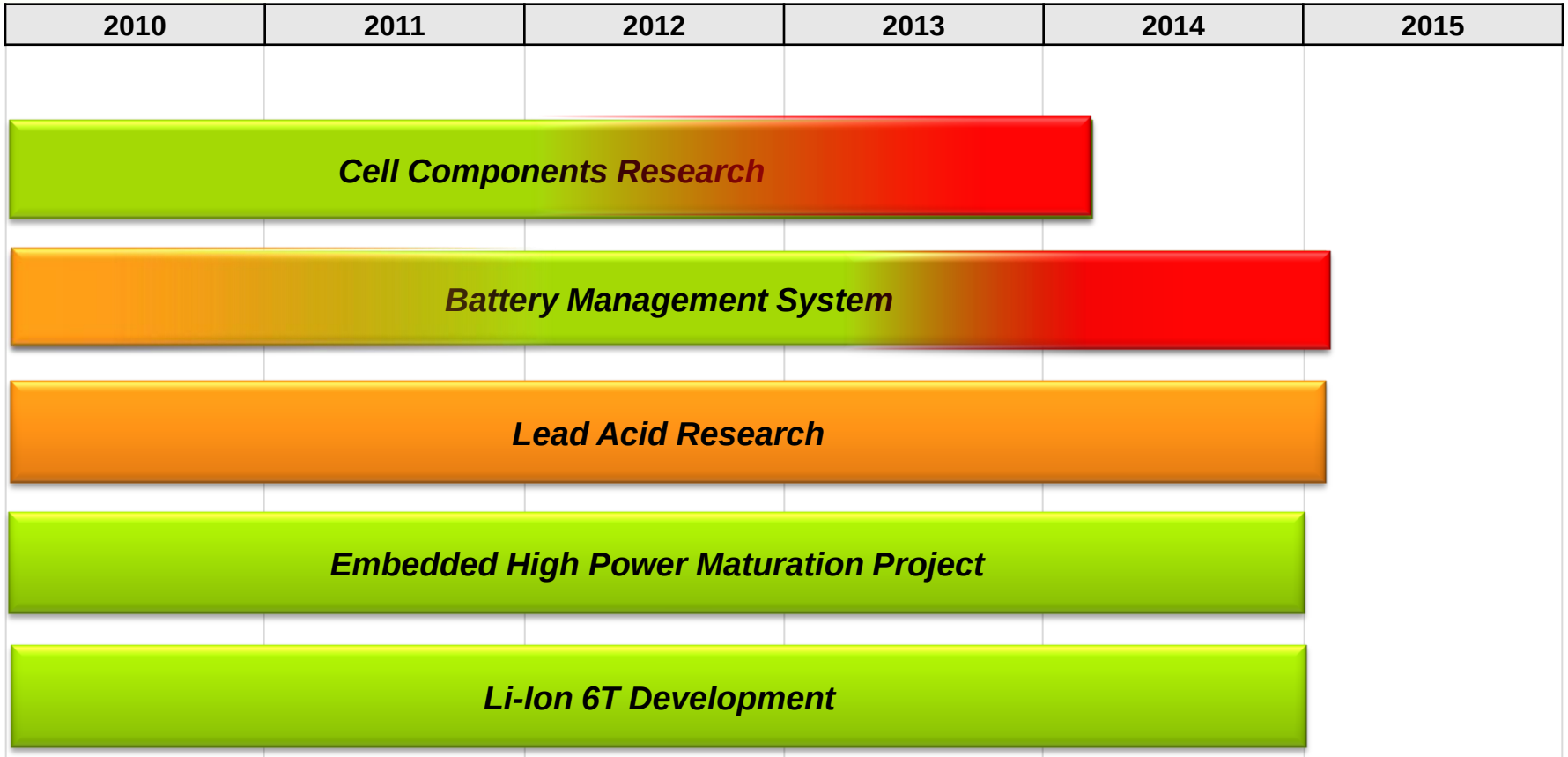
NAVSEA

Industrial Developers

Battery Partners

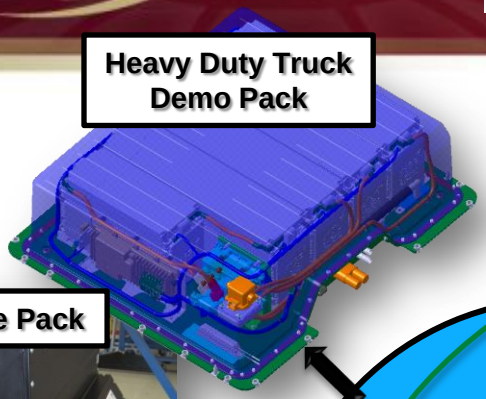
RDECOM Technology to the Warfighter Quicker

Energy Storage Technology Areas of Research



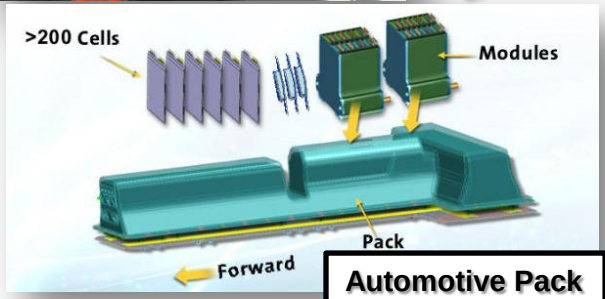
Commercial vs. Military Energy Storage Requirements

Heavy Duty Truck Demo Pack



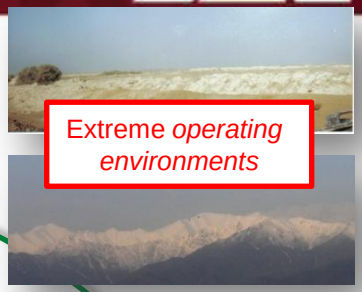
Automotive Pack

Automotive Pack



Automotive Pack

Divergence of Military and Commercial Requirements:



Extreme *operating environments*

Customer specific forms

Commercial Focus

- Fuel Economy/Hybridized vehicles
- Increased energy – EV applications
- Increased power – HEV applications
- Cost ($250/kWhr)
- Life (cycle/10-15 year calendar life)
- Safety
- SAE Standards
- Operation from to -20°C to +55°C

Military *Requirements*:

- ✓Operating Temperatures: **-46°C to 71°C**
- ✓Storage Temperatures: **-54°C to 88°C**
- ✓Electromagnetic Interference: MIL-STD-461F
- ✓Ballistic Shock: MIL-STD-810G
- ✓Life Fire: MIL-STD-810G
- ✓Explosive Environment: MIL-STD-810G
- ✓Altitude to 60,000ft: MIL-STD-29595
- ✓Explosive Decompression: MIL-STD-810G
- ✓Salt fog: MIL-STD-810G
- ✓Sand and Dust requirements: MIL-STD-810G

Additional Military Focus:

- ✓NATO **Standardized** Form Factors (i.e. 6T)
- ✓Maximized Power AND Energy density
- ✓Sustainability and Logistics issues
- ✓Silent Watch/Silent Mobility
- ✓On-board Electric Power

Standardized Military Batteries (i.e. 6T)
Used in 95% of Military Vehicles

Commercial

Military

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Li- Ion Battery Performance at Extreme Conditions

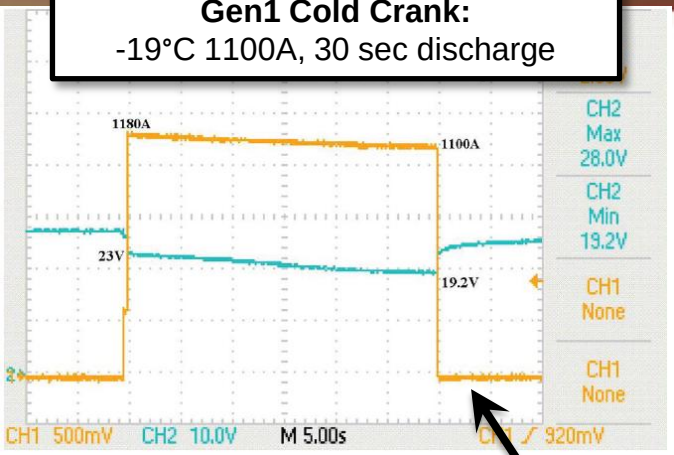
- **Low temperature operation (-40°C)**
  - Difficulty meeting startup requirements
    - Reduced power from increased impedance
  - Reduced discharge current and capacitance
  - Reduced charge acceptance/ Li Plating
  - ✓ Battery heater can be added
  - ✓ New electrolytes and additives are being developed

- **High temperatures operation (70°C)**
  - ✓ Improves battery performance
    - Increased electrochemical reactions
  - Reduced lifetime
    - Increased corrosion
  - Increased safety hazard

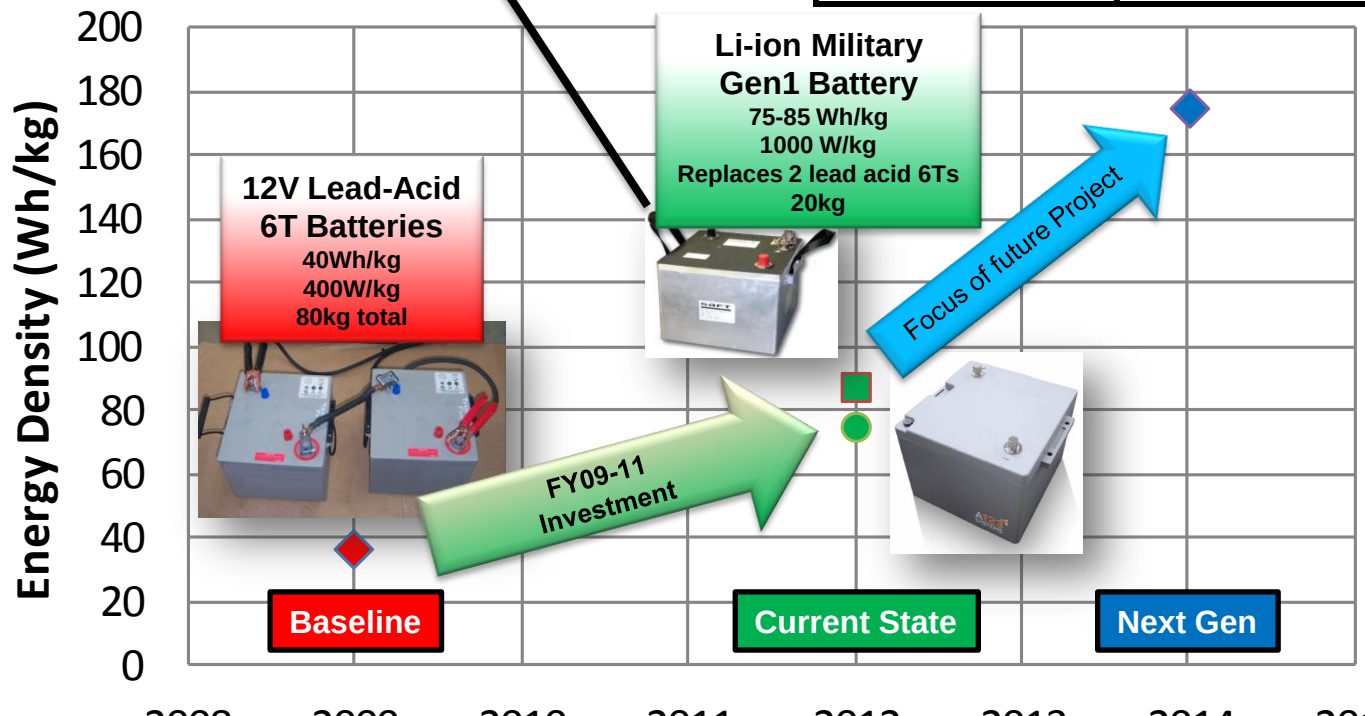
- **Optimization**
  - ✓ Operating temp between 0-50°C
  - ✓ Uniformity within and between modules

Li-ion 6T Development

Gen1 Cold Crank:
-19°C 1100A, 30 sec discharge



	Baseline 6T Lead acid	Generation 1 Li-ion 6T	
		Vendor A	Vendor B
Voltage	12V	24V	24V
Capacity (rate)	120Ahr (C/20)	60Ahr (C-rate)	70Ahr (C-rate)
Peak Current (-19C, 30sec)	1100A	>900A	1100A
Deep Cycle Life (100% DOD)	120	500-1000	500-1000
Weight	40kg	20kg	20kg
Energy Density	36Wh/kg	75Wh/kg	88Wh/kg



Project Targets:
170 Wh/kg
1500 W/kg
1000 Cycles
1400A

Accomplishments to date:

- Developed Gen1 Li-ion 6T batteries
- Demo 2x increase in energy density
- Cut weight of 6T in half (20kg vs. 40kg)
- Demo starting of HMMWV with single Gen1 24V battery (replaces 2 LA 6T!)
- Gen1 TRL 5/6 testing underway.
- Gen1 batteries to be field tested.

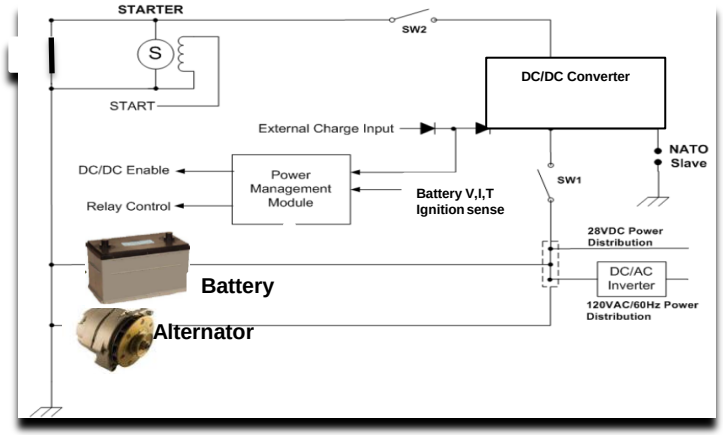
Battery Management System

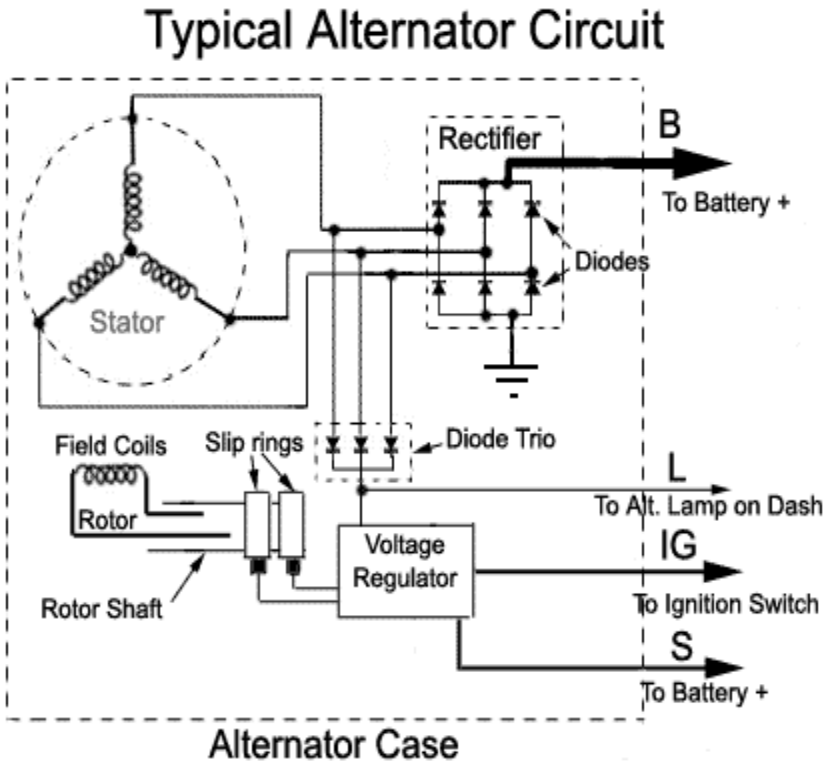
- **Needed to reduce safety hazard**
- **Required to increase battery life**
- **Monitors and reports**
  - State of Charge (SOC)
  - State of Health (SOH)
  - Voltage
  - Current
  - Temperature

- **Design challenges**
  - Handling transient spikes
    - Over-charge
    - Over-discharge
    - Over-current
  - Affordability
  - Varied charge/discharge methods
  - Communication interface
  - Battery self-discharge

Battery Charging

- The charge control for lithium ion battery chemistries is different from those of flooded and sealed lead acid batteries.
- The discharge control for lithium ion battery chemistries is different from those of flooded and sealed lead acid batteries.
- Battery charging voltage changes with the temperature

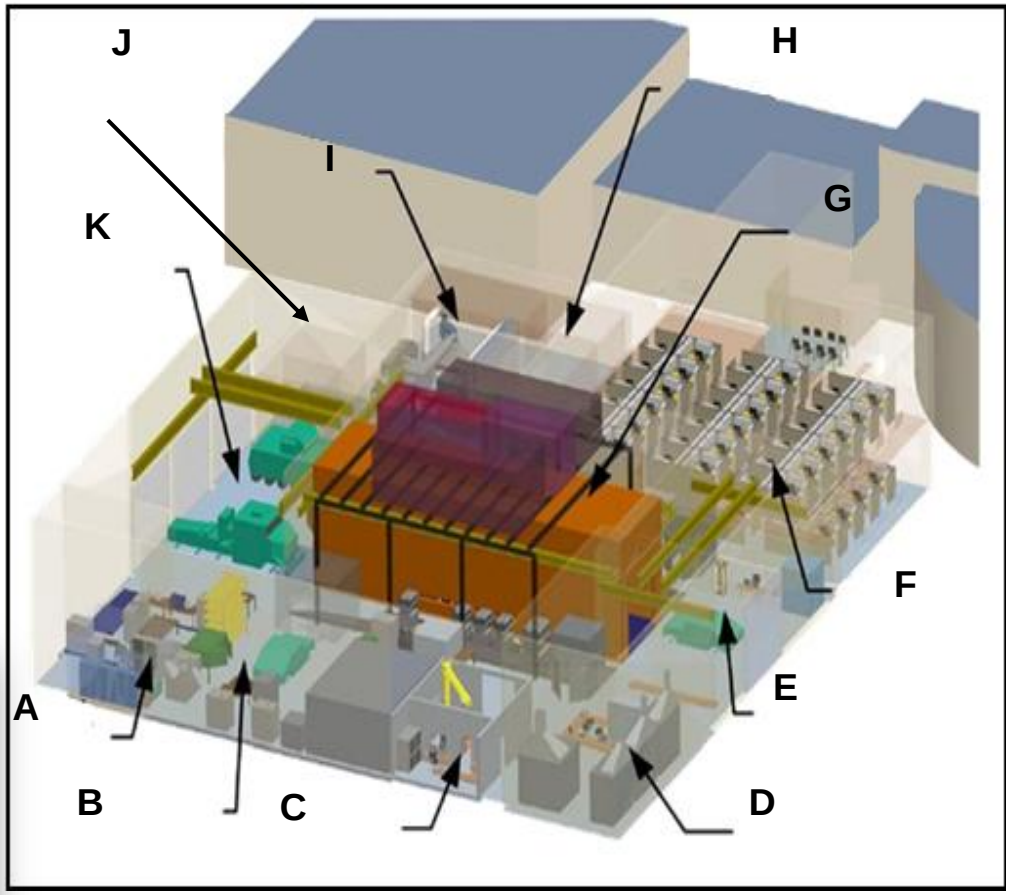




Ground Systems Power and Energy Laboratory (GSPEL)

Capabilities

- Provides steady state and transient (mission profile based) testing
- Ability to test current and emerging classes of ground vehicles
- 32,000 ft^2 of laboratory space
- Environmental chamber able to test between -60^o to 160^o F with winds up to 60 mph
- Provides 10 dynamometers to allow testing of up to 5 axle wheeled vehicles



Grand Opening April 11, 2012

B: Battery lab

TARDEC Energy Storage Labs:
GSPEL Energy Storage Lab

Purpose:

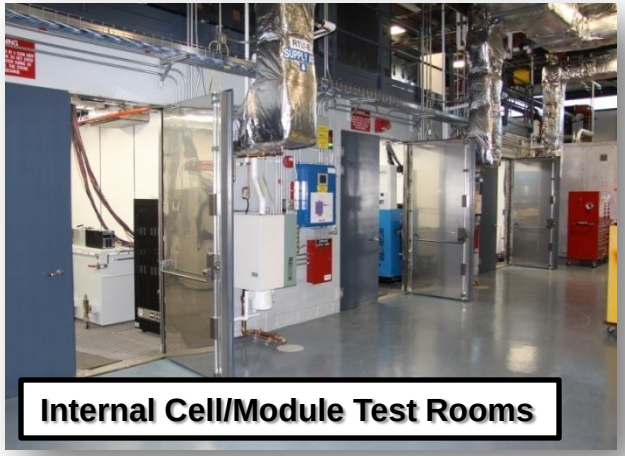
The GSPEL Energy Storage Lab is TARDEC's testing laboratory and will be used to safely analyze, evaluate and test battery and other electrochemical technologies at the cell, module level, and pack level.

Capabilities:

- Characterize and evaluate advanced technologies (lithium-ion, nickel-zinc, lead acid, ultra capacitors families, and any future new chemistry that is developed)
- Centrally controlled and monitored cycler circuits of varying current and voltage capabilities
- Characterization at different charge/discharge rates/temperatures/life cycling/pulse power/stand testing/& drive profile cycling
- Temperature test ranging from -73°C to 200°C.
- Lead acid batteries battery life analysis

Water Baths

Cell, Module and Battery Cycling Equipment



Internal Cell/Module Test Rooms

Equipment:

- 3 blast proof rooms
- 2 pack external battery pack test chambers
- ~100 cell level cycler channels
- ~100 (0-60V) module/pack level cycler channels
- 6 pack test cycler channels (AV900)
- 12 environmental chambers
- 6 water baths for testing Pb Acid batteries
- Accelerated rate calorimeter

TARDEC Energy Storage Labs:
GSPEL Energy Storage Lab Safety Features

Safety Features:

- The rooms are designed to withstand 25 psi
- Room and doors are designed to withstand this pressure and actually hold it for a controlled release.
- Walls are ~8 inches thick concrete and are re-enforced with tie rods.
- 100% air is replaced 8 times per hour. In emergency, air changes increase to 24 per hour.
- All air is passed thru a scrubber located on the roof.
- Sensors include heat, smoke, hydrogen, and organic vapors
- Fire suppression includes - Nitrogen/Argon gas fire suppression, water sprinkler system, and capability to flood the room
- E stops located in the control room, test chamber, and outside the rooms shut down all electrical equipment operating in the room and feeding the room from the mezzanine.
- Spill containment is located under the floor to contain and control spills.


Cyclers


Analog & Digital I/O

Environmental Chamber

ARC

TARDEC Energy Storage Labs:
Electrochemical Analysis & Research Laboratory

Purpose:

The EARL is TARDEC's testing laboratory for analyzing and evaluating battery and other electrochemical technology at the cell & module level. Testing in this laboratory aids TARDEC in understanding new breakthrough technologies for Army ground vehicle energy storage systems.

Capabilities:

EARL contains a number of battery cyclers for charging and discharging batteries, along with thermal chambers and a centralized control system that enables assessment of electrochemical cells with a variety of tests including:

- Characterization at different charge/discharge rates and temperatures
- Life cycling
- Hybrid pulse power characterization
- Stand testing
- Tests are monitored with thermocouples and video feed

Equipment:

Three Battery Cyclers

- 16 & 4 Channel Bitrode, 4 Channel Maccor
- Two Solartron SI 1287 Electrochemical Impedance Spectrometers
- Parstat 2273 Potentiostat
- Walk-in Hood with 4 chamber fire suppression system
- Three Tenny thermal chambers
- Centralized Control System

Battery Cycling Equipment

Thermal Chambers & Exhaust Hood

Electrochemical Characterization

TARDEC Energy Storage Labs:
Battery Management System Lab

Purpose:

Hardware-in-the-loop (HIL) Battery Simulator

The Battery Management System (BMS) laboratory is TARDEC's Lab for analyzing and evaluating prototype, near production ready, and commercial-off-the-shelf BMS units for lead acid and Li-ion batteries. BMS evaluation in this lab supports the PM/PEO to determine if the system is ready for fielding. Testing also aids TARDEC in updating the BMS specification that is used by the customer for battery management qualifications that will be used in fielded vehicles.

Capabilities:

The BMS lab contains

- BMS Hardware-In-the-Loop (HIL) which can simulate a battery profile
- Thermal chambers
- Analog and digital input/output (I/O)
- Centralized control system

Thermal chambers

Equipment Specification:

Centralized data acquisition & control system

- BMS HIL – Independently simulate and control up to 180 cells from 0 to 5 volts.
- Pack voltages up to 750V can be simulated.
- Large Thermal Chamber – 8 cubic feet, remotely programmable from -73°C to 200°C.
- Two Small Thermal Chambers – 1 cubic foot, remotely programmable from -73°C to 200°C.
- Independent Data Acquisition (I/O)
    - 16 channels of digital input
    - 16 channels of digital output
    - 16 channels of analog input
    - 16 channels of analog output
    - 16 channels of thermocouple
- Centralized Control System – control all lab equipment

It's All About The Warfighter







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